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Abstract: The periscope and chimney graft technique provides a simpler, less invasive way to maintain blood flow to the renovisceral arteries during urgent endovascular aortic repairs. The very low 30-day mortality rate and the stability of the repairs in the midterm are encouraging. This technique has the potential to profoundly influence the treatment of acute aortic pathologies.

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◆ CLINICAL INVESTIGATION ◆

Multiple Periscope and Chimney Grafts to Treat Ruptured Thoracoabdominal and Pararenal Aortic Aneurysms

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Purpose: To report midterm outcomes after urgent endovascular repair of ruptured pararenal or thoracoabdominal aortic aneurysms using multiple periscope and chimney grafts to preserve renovisceral branch perfusion and facilitate aneurysm exclusion.

Methods: Nine consecutive men (mean age 72±14 years, range 40–88) presenting with ruptured thoracoabdominal (n=6), pararenal (n=2), or infrarenal (n=1) aortic aneurysm underwent urgent endovascular repair with at least 1 periscope graft delivered via a transfemoral access; chimney grafts were installed from an axillary access. In all, 17 periscope and 7 chimney grafts were used to reperfuse 11 renal and 13 visceral arteries in the 9 patients. The aortic aneurysms were excluded using thoracic devices (n=7), an aortic extension cuff (n=1), and bifurcated stent-grafts (n=2).

Results: All procedures were completed without technical complications except for a dislocated stent-graft from the right renal artery; the artery could not be re-accessed, and the right kidney was sacrificed. One patient died of multiple organ failure (11% 30-day mortality). At a mean follow-up of 10 months (range 3–24), 5 of the 9 patients had recovered completely; 3 patients died of unrelated causes. Imaging showed no aneurysm growth in any patient, with a mean 20% shrinkage in aneurysm size. All periscope and chimney grafts remained patent, and no aortic stent-graft migration was observed. Renal function and the glomerular filtration rate remained stable in all patients.

Conclusion: The periscope and chimney graft technique provides a simpler, less invasive way to maintain blood flow to the renovisceral arteries during urgent endovascular aortic repairs. The very low 30-day mortality rate and the stability of the repairs in the midterm are encouraging. This technique has the potential to profoundly influence the treatment of acute aortic pathologies.

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Key words: endodebranching, renovisceral arteries, chimney graft, periscope graft, stent-graft, endograft, ruptured aortic aneurysm, ruptured thoracoabdominal aortic aneurysm, ruptured pararenal aortic aneurysm, ruptured AAA, endovascular aneurysm repair

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Most patients presenting with rupture of a thoracoabdominal or pararenal aortic aneurysm (TAAA and PAAA, respectively) do not survive an open repair. Moreover, surviving patients experience many postoperative complications and have lengthy hospital stays,[1] as well as serious and long-lasting morbidity.[2] Analogous to ruptured abdominal aortic aneurysm (AAA), in which endovascular aneurysm repair (EVAR) has been shown to significantly increase patient survival,[3] it is expected

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that endovascular repair of ruptured TAAAs and PAAAs should offer similar benefits. Actually, most of these cases cannot be treated using branched stent-grafts as this complex treatment can only be provided in a few centers having the necessary skills and off-the-shelf devices that are just now being proposed or developed.[4] The chimney graft and, more recently, the periscope graft techniques have been shown to be effective in maintaining blood flow to the renal and visceral arteries.[5–9] By combining the periscope and chimney techniques, we were able to treat ruptured TAAAs and/or PAAAs using standard endovascular devices, aortic stent-grafts, and peripheral stents or stent-grafts. In this report, we describe our experience in a consecutive series of patients treated with the multiple periscope and chimney graft (MPCG) technique applied to the renovisceral vessels.

METHODS

Patient Population

From August 2008 to April 2011, 9 consecutive men (mean age 72±14 years, range 40–88) presenting with ruptured thoracoabdominal (n=6), pararenal (n=2), or infrarenal (n=1) aortic aneurysms underwent urgent endovascular repair with the MPCG technique (Table). All patients presented periaortic, mediastinal, pleural, and/or retroperitoneal hematoma. Most patients had at least 2 risk factors for open surgery: age >70 years (n=7), reduced glomerular filtration rate (GFR; n=1), heart disease or reduced ventricular function (n=7), severe chronic pulmonary disease (n=5), peripheral occlusive disease (n=2), and hostile abdomen after prior aortic surgery (n=3). Five patients had been treated for an aortic aneurysm: 1 open aortic arch repair, 3 open repairs for ruptured AAA, and 1 EVAR for AAA. The 4 AAA patients presented a high-risk profile for paraplegia. Mean aortic aneurysm diameter was 94.8±39.9 mm (range 57–185). Data were collected prospectively on these patients in our clinical information system (KISIM 4.91; CISTEC AG, Zurich, Switzerland) and analyzed retrospectively in April 2011. Informed consent regarding the procedure and the use of

TABLE
Patient Characteristics

Sex/Age, y	Aortic Disease	Aortic Diameter, mm	Previous Aortic Surgery/Hostile Abdomen	Hemodynamic Status	Comorbidities
1. M/58	TAAA CR-III	185	—	Shock*	CRF
2. M/77	PRAA	102	—	Shock	CD
3. M/40	TAAA CR-V	119	—	Shock	CD
4. M/81	TAAA CR-IV	57	—	Stable	CD, COPD
5. M/77	TAAA CR-IV	66	Yes/yes	Stable	COPD, PAD
6. M/71	TAAA CR-II	72	Yes/yes	Stable	CD
7. M/77	AAA (EL Ia)	63	—	Stable	CD, COPD, PAD
8. M/76	TAA CR-I	86	Yes/no	Shock	CD, COPD
9. M/88	PRAA	103	Yes/yes	Shock	CD, COPD

AAA: infrarenal abdominal aortic aneurysm, CD: cardiac disease, COPD: chronic obstructive pulmonary disease, CR: Crawford, CRF: chronic renal failure, EL: endoleak, PRAA: pararenal aortic aneurysm, PAD: peripheral artery disease, TAAA: thoracoabdominal aortic aneurysm.
* Shock was defined as systolic blood pressure/heart rate <1.

anonymized data for analysis was obtained from all patients. All patients were followed with computed tomographic angiography (CTA), laboratory tests, and clinical examination at 3 and 6 months postoperatively and annually thereafter.

Hemodynamic Stabilization

All patients were treated according to our standard protocol for ruptured aorta patients.[10] If systolic blood pressure was >100 mmHg, it was actively lowered with vasodilators and beta-blockers to reach a systolic blood pressure of ~90 mmHg. Three of 5 unstable patients could not be stabilized, so the endovascular repair was performed immediately as a damage control procedure. The remaining patients were stabilized and/or maintained in stable condition, and the MPCG procedure was performed once acid-base imbalance and coagulation defects were corrected.

Endovascular Repair

Most patients were referred with useful and good quality CT studies, but in some cases, the aortic arch and/or femoral arteries were not fully depicted, so thoracoabdominal CTA, including the latter regions, was repeated.

Three patients were treated under local anesthesia (Table, cases 1, 3, and 8). Based on the anatomy of the aortic aneurysm and the target renovisceral vessels, a tailored approach was predefined for each patient. All vessels that were patent on preoperative CT were addressed. Chimney grafts were used to extend the proximal landing zone and periscope grafts to extend the distal landing zone. Access to each renovisceral artery and the aorta were obtained through separate remote accesses, mostly with the Surgiclose technique,[11] to avoid extensive vessel preparation. The axillary artery was used as the access site for the chimney endograft technique, and a transfemoral access was used for the periscope grafts. Branch cannulation was generally achieved using a 45-cm Arrow sheath (Arrow International Inc., Reading, PA, USA), a 5F-Chuang visceral reverse curve catheter (Cook Inc., Bloomington, IN, USA), and a Rosen wire (Cook Inc.). The same procedure was repeated for each renovisceral branch. After cannulation, the periscope and/or chimney endografts [usually Viabahn (W.L. Gore & Associates, Flagstaff, AZ, USA) or Fluency stent-grafts (C.R. Bard, Inc., Murray Hill, NJ, USA) measuring 5 to 13 mm in diameter and 5 to 10 cm in length] were positioned in the target arteries and deployed with the distal end inserted about 1 to 2 cm into the target vessel. To achieve safe anchoring, corresponding angioplasty balloons (2 cm in length) were used to fully expand the branch grafts at their anchoring/landing zone. A kissing balloon technique completed the procedure by achieving full expansion of all the stent-grafts (aortic, periscopes, and chimneys). In one patient (case 6), with rupture of a Crawford II TAAA, open debranching of the celiac trunk and superior mesenteric artery (SMA) was performed first, and the renal periscope endografts were deployed using a sandwich technique[12] some days later.

Overall, 24 renovisceral arteries (mean of 3 per patient) were addressed with the MPCG technique for ''endodebranching'' of 11 renal arteries (7 right, 4 left) and 13 visceral arteries (6 SMA and 7 celiac trunks) using 17 periscope endografts and 7 chimney endografts. All patients had at least 1 periscope endograft. Most periscope and/or chimney endografts were constructed from stent-grafts (21/24, 88%); bare stents [Wallstent (Boston Scientific, Natick, MA, USA) or Palmaz Blue (Cordis, a Johnson and Johnson company, Miami Lakes, FL, USA)] were used occasionally. Aortic aneurysms were sealed using thoracic stent-grafts (n=7), aortic extension cuffs (n=1), and/or bifurcated stent-grafts (n=2). In all cases, proximal and distal landing zones of the aortic stent-grafts were >2 cm. Once all devices were implanted, completion angiography and selective pressure measurements distal to the aortic devices and any branch devices were performed to exclude significant pressure gradients. In case of a significant pressure drop, additional kissing balloon inflation (n=2) and/or stenting (n=2) was performed. Any significant high-flow endoleak seen filling the aneurysm sac totally or partially in the arterial phase of the pre-discharge CTA was corrected. Low-flow type I endoleaks filling the aneurysm sac only during late-phase CTA and type II endoleaks were managed conservatively so

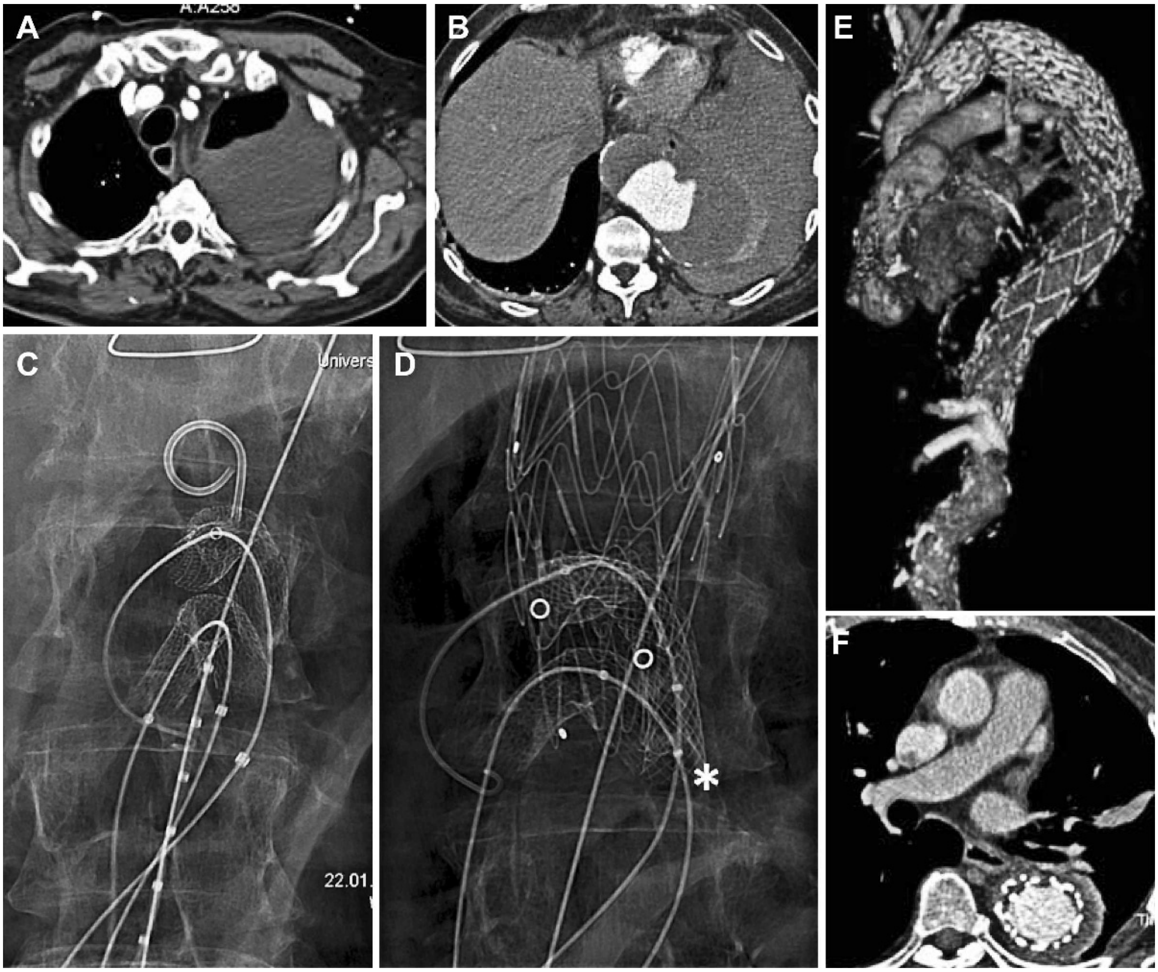

Figure 1 ◆ (**A**,**B**) Intrathoracic hematoma extending from the apex to the diaphragm in a patient with a Crawford I TAAA (case 8). (**C**) Transfemoral implantation of periscope grafts in the celiac trunk and superior mesenteric artery. (**D**) After aortic stent-graft deployment, a pressure gradient was detected on the celiac periscope and treated with additional stenting. The asterisk marks the Wallstent. (**E**) CT reconstruction after endovascular repair with the MPCG technique. (**F**) CTA after thoracic hematoma evacuation.

long as the periaortic hematoma and/or aneurysm sac diameter did not enlarge.

Large hematomas in the thorax were evacuated in 3 patients (Fig. 1). Postprocedure CTA confirmed sufficient sealing of the aortic aneurysm and normalization of coagulation parameters. In these cases, chest tubes were not connected to a negative pressure system, but only to gravity drainage.

RESULTS

All procedures were completed without technical complications, except for 1 patient (case 2) in whom a branch stent-graft became dislocated from the right renal artery. This artery could not be re-accessed, and the right kidney was sacrificed. The endovascular repair with the MPCG procedures stabilized the hemodynamics in the 3 unstable patients requiring immediate aortic repair who did not responding to blood pressure lowering (cases 1–3). One patient (case 3) with a ruptured Crawford I aneurysm required resuscitation and pericardial drainage because of pericardial tamponade. After this event, hemodynamics normalized completely, and the patient was extubated and recovered. Only 1 patient (case 2) died

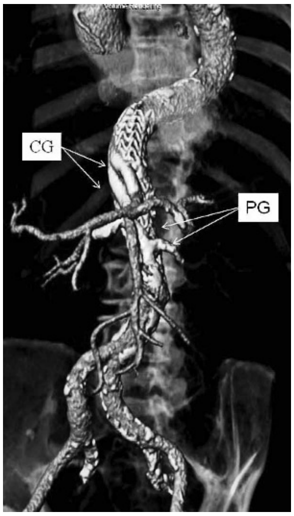

Figure 2 ◆ Postoperative CT reconstruction after endovascular repair with 2 renal periscopes (PG) and 2 visceral chimneys (CG) in a patient with a Crawford type IV TAAA (case 4).

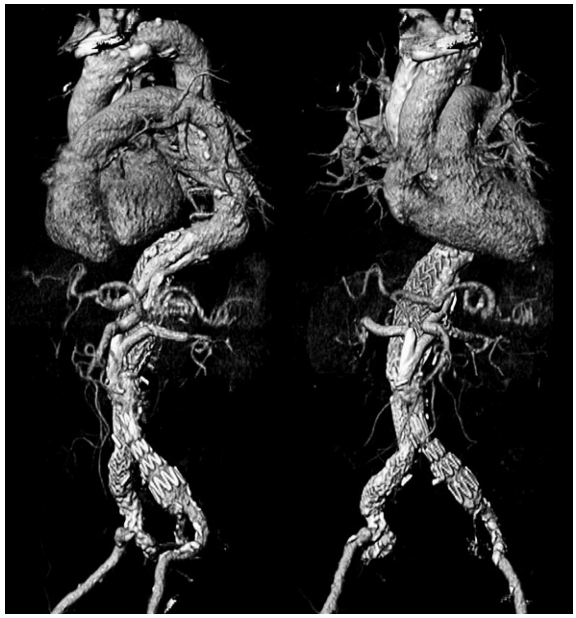

Figure 3 ◆ The CT images from patient 5 at 2 years post repair show no endoleak or device migration; the aneurysm has nearly disappeared, and all chimney and periscope grafts are patent.

postoperatively from multiple organ failure on postoperative day 9 (11% 30-day mortality).

Endoleaks and Secondary Procedures

Postprocedural CTA revealed endoleaks in 6 patients. Of these, 1 type Ib/III and 1 type Ia endoleak required treatment. In one of our early patients (case 3), a mixed endoleak (Ib and II) originated from a bare metal stent (Wallstent) that was used to maintain perfusion to the celiac trunk. This was corrected on the 4th postprocedure day by relining the stent with a Fluency stent-graft. One patient (case 7) developed a secondary high-flow type Ia endoleak. Despite that, the periaortic hematoma decreased in size significantly. However, the situation was considered unstable, and a secondary repair was performed on the 14th postprocedure day to redo the MPCG with cuff implantation and glue embolization. Pre-discharge CTA confirmed complete sac sealing and a slight decrease in aortic aneurysm sac diameter.

Follow-up

At a mean follow-up of 10 months (range 3–24), 5 of the 8 surviving patients had recovered completely and returned home. Three patients subsequently died during follow-up. The first patient in our series (a ruptured syphilitic Crawford type III TAAA) developed a late aortoesophageal fistula and graft infection, requiring open graft repair and partial resection of the esophagus. The patient declined further therapy after paraplegia occurred, and the patient died 3 months postoperatively. An 81-year-old patient (case 4) treated for a mycotic pararenal aneurysm and pyogenic spondylodiscitis (T12–L1) recovered from the aortic procedure (Fig. 2) but died after operative treatment of the spinal problem 3 months after the aortic procedure. The third patient (case 6), treated for a ruptured Crawford type II aortic aneurysm, developed paraplegia 6 weeks after the procedure. He subsequently developed a sacral wound, which became infected. The patient died after surgical treatment of that wound 13 months after his aortic procedure.

CT follow-up showed no aneurysm growth in any of the patients. Overall, there was 20% shrinkage in aneurysm size to 80.3±37.4 mm (range 51–169). All of the periscope and chimney endografts remained patent, and there was no aortic stent-graft migration (Fig. 3). Endoleaks were noted in 2 patients. One patient (case 6) had persistent low-flow type III endoleak originating from the overlap between 2 aortic stent-grafts at the thoracoabdominal junction. The patient was absolutely stable after the endovascular repair. Inasmuch as the aneurysm size decreased significantly during follow-up, there was no need to treat the leak. The other patient (case 8) had a persistent type Ib endoleak in the region of the distal landing zone. As the aneurysm size decreased significantly during follow-up, this endoleak was treated conservatively. Renal function remained stable in all patients, with no significant change in the GFR over time.

DISCUSSION

As Cowan et al.[1] reported in 2003, the mortality rate in US centers after urgent open graft repair of ruptured TAAAs and PAAAs remains around 55%, which is true for our center and the majority of EU centers. There is, therefore, a need for better techniques to treat these patients. The fenestrated and/or branched stent-graft technique has so far been used in only a single ruptured TAAA (Crawford type IV). In this case report, published some years ago,[13] the authors stated that this experience would probably remain unique. To our knowledge, this statement still holds true.

The published experience with renovisceral periscope and chimney grafts seems promising.[5–9] Following our first reports of successful treatment of 3 patients with ruptured TAAAs using the periscope graft technique,[5,6] subsequent reports[12,14–19] have shown similar favorable outcomes with multiple chimneys and/or periscope grafts in ruptured or acute thoracoabdominal or pararenal cases. In our present updated series of 9 consecutive patients, this approach provided a simpler way to revascularize renovisceral aortic branches in an urgent situation using in-stock devices. This less invasive technique lowered morbidity and mortality in the difficult setting of a ruptured TAAA or PAAA. In our series, 30-day mortality was only 11%, comparable to the pooled mean mortality rates of case reports or smaller series published so far.[12,14–19] Midterm results at 10 months showed consistent aneurysm sac shrinkage and maintained blood flow to the renovisceral arteries in all survivors. Moreover, the quality of life was excellent for all patients surviving to discharge, except the patient who developed late paraplegia.

Since the periscope and chimney techniques can be performed by interventionists experienced with EVAR, this technique could become a valuable treatment option in most ruptured TAAAs and/or PAAAs. Since survivors of ruptured TAAAs or PAAAs have a limited life expectancy, this repair method could be considered a definitive treatment in most patients. Inasmuch as long-term durability is not yet proven, the MPCG technique can be considered as a bridging procedure to solve the acute problem in the younger patient.

Endoleaks are reported to be an issue in the periscope/chimney graft technique.[20] Our policy concerning periprocedural endoleaks in ruptured TAAA/PAAAs has evolved during our 14 years' experience in treating ruptured AAA using EVAR.[10] We consider 2 types of primary endoleaks detected on-table during the procedure. "High-flow" (HF) endoleaks appear immediately during contrast injection and "low-flow" (LF) endoleaks are significantly delayed. In our experience, hemorrhage could effectively be controlled in the presence of some LF endoleaks. Moreover, LF endoleaks encountered in patients with severely disturbed coagulation disappear for the most part once coagulation normalizes. Regarding secondary endoleaks detected on postprocedural CTA, we tolerate LF endoleaks, especially if the periaortic hematoma and/or aneurysm sac regress. However, all HF endoleaks and LF endoleaks in which the periaortic hematoma and/or sac expand are treated.

There are some general limitations to the technique. For the construction of chimney endografts, the access through the subclavian artery and the aortic arch has to be safe. Any floating plaques in front of the supra-aortic trunk carry a very high stroke risk and represent, in our experience, a contraindication to the chimney technique. For the periscope technique, the iliac arteries have to be patent.

Multiple periscope and chimney grafts might be an issue as regards aneurysm sealing. Moreover, the more chimney/periscope grafts, the more the aortic lumen is narrowed at the level of the landing zone(s). This might be problematic in aortas with a diameter of

≤16mm, especially for periscope grafts that are perfused in a retrograde manner and depend on distal aortic perfusion.[21]

Some degree of branch disease can be managed, but the target artery should have a minimal diameter >4 mm and a safe landing zone >1 cm. The MPCG technique requires high-end imaging tools. Multiple periscopes and/or chimney grafts burden the view, and standard fluoroscopy makes it impossible to determine exactly the location of each stent-graft; therefore, the risk of technical failure is high. Finally, overall experience with the MPCG technique is still limited but growing rapidly, and long-term follow-up is not yet well documented.

Conclusion

The multiple periscope and chimney endograft technique is a less invasive method of facilitating endovascular repair using in-stock devices in the difficult setting of a ruptured thoracoabdominal or pararenal aneurysm. Therefore, the MPCG technique has the potential to profoundly influence the treatment of acute aortic pathologies in the future.

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